VENTILATORY CAPACITY AND PRODUCTIVE COUGH IN A RURAL COMMUNITY

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The wider adoption of the Medical Research Council's questionnaire on respiratory symptoms has been an important step in enabling more accurate comparisons of pulmonary morbidity and risk factors between various environments. Objective evidence of respiratory function also forms an essential part of these epidemiological studies if confident conclusions are to be established. In this regard, the study by Lowe, Pelmeier, Campbell, Hitchens, Khosla, and King (1968) of steel workers in South Wales has established criteria for ventilatory function of value for objective comparisons with other populations. Hong, Gandevia, and Lovell (1967) assessed the presence of phlegm by listening for audible loose cough in their subjects, and considered this test to be a reliable and simple measure of sputum production suitable for a variety of clinical and epidemiological purposes.

In 1966, a longitudinal study in the rural population of Busselton, Western Australia, was commenced and one of its aims was to assess the predictive validity of various measurements relating to subsequent pulmonary and cardiovascular morbidity. This population was known to have a low incidence of respiratory disorders (Cullen, Stenhouse, Welborn, McCall, and Curnow, 1968). The study aimed to establish for Busselton norms

of ventilatory capacity, to assess the empirical value of the productive cough test of Hong *et al.* (1967) and to make comparisons between South Wales and Busselton of the effect of age on ventilatory capacity.

METHODS

In the summer of November-December 1966, various circulatory, respiratory, and metabolic conditions were investigated in a survey of the population of Busselton, a rural township on the south-west coast of Western Australia. The environmental conditions include a mediterranean type of climate, a 34-inch annual rainfall, no known industrial air pollution, and little atmospheric dust in any season. The population of the town and surrounding areas in 1966 was about 6,500, the town serving surrounding farmers, timber millers, titanium miners, fishermen, and tourists. Approximately 91 per cent. of the population of 21 years of age or more was studied, comprising 1,638 male and 1,693 female subjects.

QUESTIONNAIRE AND MEASUREMENTS

The questionnaire on respiratory symptoms described by the British Medical Research Council (M.R.C.Q.) in 1966 was used by doctors to obtain

subjective evidence of the prevalence of respiratory disorders in this Busselton community.

Objective evidence of sputum production was obtained using the techniques described by Hong *et al.* (1967). Each of the 1,638 men was asked to take a deep breath and then to cough forcibly. This was repeated on three successive occasions, the resulting cough being recorded as 'loose' or 'dry' as judged by auditory impression on agreement by two trained observers.

After the cough test in each male subject, the forced expiratory volume at one second (F.E.V._{1.0}) and the forced vital capacity (F.V.C.) were recorded by means of a McDermott dry spirometer. The subjects' results were recorded as the highest of three successive measurements, provided that two of the recordings were within 10 per cent. of each other. Occasionally, therefore, more than three readings were required. Daily standardization of the spirometer was undertaken. Each of the four trained operators took daily F.E.V._{1.0} and F.V.C. measurements from one another with no significant variations in their daily records. The acceptance of the highest of three blows followed the recommendations of the U.S.A. Committee on Rating of Mental and Physical Impairment (1965). In a survey of 18,944 men in South Wales, Lowe *et al.* (1968) chose one practice blow and the highest of two successive blows—an almost identical method to that used in Busselton. Gandevia (personal communication) found no pertinent difference between recording the highest or the mean of several attempts. The ratio of the forced expiratory volume and forced vital capacity was expressed as a percentage (F.E.V._{1.0}%).

Electrocardiogram estimations were performed on each subject in addition to other biochemical and haematological measurements not directly related to pulmonary disease.

RESULTS

The prevalence of respiratory disorders in the Busselton community has been previously reported by Cullen *et al.* (1968). As in rural Tecumseh, Michigan (Payne and Kjelsberg, 1964), about 2–3 per cent. of non-smokers reported chronic bronchitis, which presents compelling circumstantial evidence that higher prevalence rates of this disorder are caused predominantly by inhaled irritants. The low prevalence at Busselton of the remaining respiratory disorders was in marked contrast to the burden of pulmonary morbidity reported from various urban societies.

In our earlier report (Cullen *et al.* 1968) the total number of smokers was given as 846. In the present publication 16 ex-smokers have been re-classified as smokers, to give a total of 862.

VENTILATORY CAPACITY IN 1,638 BUSSELTON MALES

Table I shows mean values for F.E.V._{1.0}, F.V.C., and F.E.V._{1.0}% according to smoking habits. Means declined steadily with increasing age, with greater declines in F.E.V._{1.0} than with F.V.C. At age 20–29 years mean values in the three categories of smokers were within about 1 per cent. of each other. After 39 years of age smokers had lower mean values and greater declines in F.E.V._{1.0}, F.V.C. and F.E.V._{1.0}% than had non-smokers.

Table II indicates that the lowest F.E.V._{1.0} readings were in the asthmatics at all ages except 40–49 years, followed by the values in the chronic bronchitics, with exposure to dust having little or no effect on F.E.V._{1.0} in this community.

Table III indicates that, in smokers of all ages, mean values of F.E.V._{1.0}, F.V.C., and F.E.V._{1.0}% were invariably lower in those with, than in those without productive cough, the extent of these differences being very similar to those between

TABLE I
VENTILATORY CAPACITY IN BUSSELTON MALES BY AGE AND SMOKING CATEGORY (1966)

	Age (years)	F.E.V. _{1.0} (litres)				F.V.C. (litres)				F.E.V. _{1.0} %			
		Non-smokers	Ex-smokers	Smokers	All Categories	Non-smokers	Ex-smokers	Smokers	All Categories	Non-smokers	Ex-smokers	Smokers	All Categories
Mean values for each age group	20–29	4.26	4.18	4.21	4.23	5.27	5.30	5.32	5.30	80.7	79.0	79.2	79.8
	30–39	3.97	4.05	3.95	3.97	5.04	5.11	5.20	5.14	78.6	79.2	75.9	77.2
	40–49	3.70	3.68	3.43	3.56	4.90	4.94	4.79	4.85	75.5	74.4	71.7	73.3
	50–59	3.30	3.13	2.91	3.05	4.50	4.46	4.42	4.44	73.4	70.0	66.0	68.4
	60–69	2.91	2.70	2.43	2.60	4.06	4.03	3.86	3.95	71.5	66.2	62.6	65.3
	70+	2.56	2.24	2.04	2.18	3.74	3.54	3.44	3.52	68.7	62.9	59.3	61.9
Standard deviation for each age group	20–29	0.54	0.52	0.59	0.56	0.53	0.61	0.57	0.56	6.3	6.1	7.3	6.8
	30–39	0.58	0.54	0.63	0.60	0.62	0.58	0.59	0.60	7.6	6.5	7.5	7.5
	40–49	0.63	0.49	0.58	0.61	0.69	0.59	0.64	0.64	7.0	7.4	8.3	7.9
	50–59	0.73	0.56	0.67	0.67	0.86	0.61	0.78	0.76	7.8	7.0	10.4	9.7
	60–69	0.59	0.70	0.66	0.69	0.73	0.77	0.79	0.78	7.2	10.9	11.1	10.9
	70+	0.64	0.59	0.72	0.69	0.85	0.75	0.90	0.85	10.4	12.3	13.9	13.3

TABLE II

F.E.V._{1.0} IN BUSSELTON MEN ACCORDING TO CHRONIC BRONCHITIS, ASTHMA, AND DUSTY JOB CATEGORIES (1966)

Age Group	Total Sample Smokers		Chronic Bronchitis (Q.10)		Asthma		Non-dusty Job (smokers)		Dusty Job (smokers)	
	No.	Mean F.E.V. _{1.0}	No.	Mean F.E.V. _{1.0}	No.	Mean F.E.V. _{1.0}	No.	Mean F.E.V. _{1.0}	No.	Mean F.E.V. _{1.0}
20-29	121	4.21	8	4.03	9	3.72	50	4.23	71	4.21
30-39	154	3.95	20	3.75	9	3.71	47	4.00	107	3.94
40-49	180	3.43	28	3.09	11	3.15	79	3.47	101	3.41
50-59	179	2.91	32	2.72	5	2.56	68	2.90	111	2.92
60-69	134	2.43	41	2.27	8	1.69	64	2.45	70	2.40
70+	94	2.04	22	1.68	3	1.56	48	2.08	46	1.99

TABLE III

VENTILATORY CAPACITY OF SMOKERS ACCORDING TO PRODUCTIVE COUGH CATEGORY, BUSSELTON MEN (1966)

Age Group	Productive Cough	Total in Age Group	Mean F.E.V. _{1.0} (litres)		Mean F.V.C. (litres)		Mean F.E.V. _{1.0} % (F.E.R.)	
			Mean F.E.V. _{1.0}	S.D.	Mean F.V.C.	S.D.	Mean F.E.V. _{1.0} %	S.D.
20-29	Negative	105	4.25	0.55	5.35	0.56	79.6	6.9
	Positive	16	4.00	0.72	5.20	0.60	76.6	7.3
30-39	Negative	121	4.01	0.61	5.23	0.60	76.5	6.8
	Positive	33	3.78	0.69	5.13	0.59	73.6	9.9
40-49	Negative	128	3.49	0.53	4.85	0.61	72.1	7.8
	Positive	52	3.31	0.68	4.65	0.68	71.0	9.2
50-59	Negative	100	2.98	0.64	4.42	0.80	67.6	9.0
	Positive	79	2.83	0.68	4.41	0.75	64.2	11.5
60-69	Negative	51	2.66	0.59	4.07	0.72	65.4	10.0
	Positive	83	2.29	0.66	3.74	0.81	60.9	11.3
70+	Negative	41	2.16	0.76	3.45	0.83	61.7	12.1
	Positive	53	1.96	0.68	3.43	0.95	57.7	14.9

TABLE IV

CORRELATION MATRIX OF FACTORS IN RELATION TO VENTILATORY CAPACITY

	Age	F.E.V. _{1.0} %	Smoking	Height	Weight	Productive Cough	F.E.V. _{1.0}	F.V.C.	Mean	Maximum	Minimum
Age	1.000	-0.553	0.108	-0.261	0.001	0.256	-0.739	-0.645	48.60	90.00	20.00
F.E.V. _{1.0} %	+++	1.000	-0.241	0.169	0.112	-0.301	0.765	0.374	71.60	100.00	10.00
Smoking	+++	+++	1.000	-0.009	-0.103	0.274	-0.186	-0.085	1.27	2.00	0
Height (m.)	+++	+++	N.S.	1.000	0.444	-0.037	0.429	0.485	1.72	1.954	1.305
Weight (kg.)	N.S.	+++	+++	+++	1.000	-0.057	0.137	0.118	73.42	120.00	42.0
Productive cough	+++	+++	+++	N.S.	+	1.000	-0.318	-0.238	0.25	1.00	0
F.E.V. _{1.0}	+++	+++	+++	+++	+++	+++	1.000	0.870	3.33	5.54	0.36
F.V.C.	+++	+++	+++	+++	+++	+++	+++	1.000	4.61	7.60	0.85

N.S. = Not significant. + P < 0.05. +++ P < 0.001.

smokers and chronic bronchitis (only 8 of 151 chronic bronchitis were non-smokers).

Further evidence of impaired ventilatory capacity in those with respiratory symptoms was provided by examining those subjects whose F.E.V._{1.0}% was in the lower tenth percentile range. Compared with those whose F.E.V._{1.0}% was above those in the lower tenth percentile range, those in the lower tenth percentile range had an increased prevalence of phlegm (M.R.C.Q. 10) (P < 0.001), cough (Q.5) (P < 0.001), wheezing (Q.15b) (P < 0.001), breathlessness (Q.14b) (P < 0.001), increased sputum attacks in the last three years (Q.21a, b, c)

(P < 0.001), and asthma (Q.28) (P < 0.001) and more of these subjects were smokers (P < 0.001). No relationship was demonstrated between those with F.E.V._{1.0}% in the lower tenth percentile range and dusty jobs, hay fever, angina, or alcohol consumption.

Table IV presents the correlations and significances, the means, maxima, and minima of the eight variables which were used in the multiple regression study. Table V gives summaries of the multiple regressions in a form similar to that used by Lowe *et al.* (1968), the figures in the body of the table being the regression coefficients. Initially, all

TABLE V
MULTIPLE REGRESSION COEFFICIENTS RELATING TO VENTILATORY CAPACITY

	Intercept	Age (years)	Smoking	Height (metres)	Weight (kg.)	Productive Cough	Age ²	S.D.	R
F.E.V. _{1.0}	-2.505132	-0.036521 †††	-0.088978 †††	3.496565 †††	— N.S.	-0.266193 †††	— N.S.	0.5601	0.7952
F.V.C.	-3.265488	-0.028910 †††	— N.S.	4.850998 †††	-0.004896 ††	-0.202879 †††	-0.000269 †††	0.6152	0.7344
F.E.V. _{1.0} %	68.1141	-0.3461 †††	-1.8431 †††	— N.S.	0.0901 †††	-3.2538 †††	— N.S.	8.747	0.6015

N.S. = not significant †† P < 0.01 ††† P < 0.001

six variables were included as determining variables, and then, step by step, those variables which did not demonstrate significance were excluded, until all remaining variables contributed significantly. The significant independent effects of smoking in two of the regressions, and productive cough in all three regressions should be noted. F.E.V._{1.0} and F.V.C. correlate with age, height, and productive cough. F.E.V._{1.0} also correlated with smoking, and F.V.C. with weight. There was a significant (although small) curvature in the relationship between age and F.V.C.

PRODUCTIVE COUGH

Table VI shows the prevalence of audible productive cough according to smoking categories, the non-smokers and ex-smokers having been pooled in view of the absence of significant differences in productive cough between them. At all age levels,

TABLE VI
PREVALENCE OF PRODUCTIVE COUGH ACCORDING TO SMOKING CATEGORY

Age	Ex-smokers and Non-smokers		Smokers		X _s Yates C.
	No.	%	No.	%	
20-29	6/136	4	16/121	13	5
30-39	10/127	8	33/154	21	9
40-49	16/168	10	52/180	29	20
50-59	16/134	12	79/179	44	36
60-69	28/131	21	83/134	62	43
70+	12/80	15	53/94	56	30
Total	88/776	11	316/862	37	140

fewer non-smokers and ex-smokers were observed with productive cough than were smokers (P < 0.001). The prevalence of productive cough in the total sample was 24.7 per cent., increasing with age until 60-69 years of age. This was compared with the prevalence of lesser grades of bronchitis such as winter cough (M.R.C.Q.1)—14 per cent.; winter phlegm (Q.6)—13 per cent.; and current

cough with or without a cold—8 per cent. The proportion of male chronic bronchitics (Q.10) with productive cough increased from 25 per cent. at 21-39 years to 63 per cent. between the ages of 40 and 70+ years. Men with productive cough were more likely in all decades to have associated chronic bronchitis (Q.10), the prevalence increasing from 9 per cent. at 20-29 years to 21 per cent. at 70+ years, compared with a bronchitis prevalence in the total sample of 3.7 per cent. at 20-29 years to 12.7 per cent. at 70+ years (P < 0.001).

TABLE VII
PRODUCTIVE COUGH AND RELATIONS WITH RESPIRATORY FACTORS, BUSSELTON MEN (1966)

Category	404 Positive Productive Cough		1,234 Negative Productive Cough		X _s
Cough (Q.5)	76	(19)	54	(4)	84.8
Phlegm (Q.10)	84	(21)	67	(5)	84.0
Recent attacks cough and phlegm (Q.12a, b)	61	(15)	101	(8)	15.6
Breathlessness (Q.14a)	118	(29)	218	(18)	24.2
Wheezing (Q.15b)	51	(13)	26	(2)	68.8
Chest illnesses past 3 years (Q.21b)	37	(9)	41	(3)	21.6
Specific chest illnesses (Q. 22-30)	215	(53)	469	(38)	28.3
Smokers	316	(78)	530	(43)	150.2
Cough last 7 days	34	(8)	49	(4)	11.6

Percentages in parentheses

Table VII outlines the relationships between observed productive cough and other respiratory factors. Those with a productive cough were more likely to have reported associated cough (Q.5), phlegm (Q.10), recent attacks of cough and phlegm (Q.12a, b), breathlessness (Q.14a), wheezing (Q.12b), chest illnesses in the past three years (Q.21b), specific chest illnesses (Qs. 22-30), and cough in the last seven days, and to be smokers. In male smokers of all ages those with a productive cough had a lower mean F.E.V._{1.0}, F.V.C., and F.E.V._{1.0}% than had those without a productive cough (Table

III). Multiple regression analysis (Table V) indicated that men with observed productive cough had a significantly lower F.E.V._{1.0} ($P < 0.001$), F.V.C. ($P < 0.001$), and F.E.V._{1.0}% ($P < 0.001$).

DISCUSSION

VENTILATORY CAPACITY

The study by Lowe *et al.* (1968) of Welsh steel-workers indicated that local norms for a particular community need to be defined in view of significant differences that occurred between neighbouring steel-working populations in both physique and ventilatory capacity. Comparisons between the South Wales data and that of Busselton indicated certain conclusions that were similar in both studies. For F.E.V._{1.0} and F.V.C., age and height were of considerable significance, but weight was of no significance with F.E.V._{1.0} and had only low correlation with F.V.C. In both studies, F.V.C. was more highly correlated with height than was F.E.V._{1.0}, and F.E.V._{1.0}% was unrelated to height and had only correlations with weight. As in Wales, it was found that the statistical use of F.E.V._{1.0}% is complicated by the standard deviation of the mean value becoming progressively greater with increasing age over 39 years of age.

Comparisons in Table VIII indicate that levels of F.E.V._{1.0} and F.V.C. varied by less than 3 per cent. between the 20–29-year-old-men of Wales and Busselton. Subsequently there was a greater deterio-

35 per cent. In view of the fact that these comparisons were made between non-bronchitic steel-workers and Busselton-Tecumseh samples that included 9–8 per cent. of bronchitics, the comparative decline in the Welsh steel-workers is probably greater than is indicated in the above data. It would be of value for future data to be published in smoking and non-smoking categories in view of significant differences in the rates of deterioration of F.E.V._{1.0} and F.V.C. between smokers and non-smokers.

Previous reports have indicated lower rural than urban morbidity using subjective means of detecting respiratory disorders. The differences with increasing age in ventilatory capacity between Busselton-Tecumseh and Port Talbot-Ebbw Vale *would appear to confirm by objective means that environments may differ significantly in their influence on respiratory function.*

PRODUCTIVE COUGH

Analysis of audible productive cough assessed by independent observers showed empirical evidence of validity by its association with two objective variables, F.E.V._{1.0} and F.V.C. Productive cough was associated with increased probability of subjective symptoms and so would appear to be an easily determined index of sputum production which could be used in a wide range of clinical and epidemiological situations.

Gandevia (1968) reported on productive cough in 941 patients attending general practices throughout Australia for reasons other than respiratory disorders. Compared with a prevalence of 11 per cent. in Busselton non-smoking men, he found an identical prevalence of productive cough in non-smokers of both sexes of 10.3 per cent. in men and 10.5 per cent. in women. He found that the rural-urban prevalence differences of about 10 per cent. for productive cough in smokers could not be explained by their smoking patterns. This increase of 10 per cent. in the rate of prevalence of productive cough in urban areas of Gandevia's subjects is consistent with the 10 per cent. increase in chronic bronchitis associated with urban environments in the United Kingdom or the United States of America (Cullen *et al.* 1968). In this connexion it is of interest that Cederlof (1966) reported a higher rural than urban prevalence of respiratory symptoms in co-twins with similar smoking habits in Sweden.

The prevalence of productive cough in Busselton's male non-smokers (11 per cent.) and smokers (37 per cent.) was considerably higher than the prevalence of chronic bronchitis (1.9 per cent. in non-smokers, 14.5 per cent. in smokers) or of lesser

TABLE VIII
COMPARISONS OF F.E.V._{1.0} AND F.V.C. BETWEEN
BUSSELTON, PORT TALBOT, AND EBBW VALE

Age	Busselton		Port Talbot		Ebbw Vale	
	F.E.V. _{1.0}	F.V.C.	F.E.V. _{1.0}	F.V.C.	F.E.V. _{1.0}	F.V.C.
20–29	4.23	5.30	4.33	5.23	4.13	5.08
30–39	3.97	5.14	3.93	4.87	3.71	4.72
40–49	3.56	4.85	3.42	4.40	3.18	4.23
50–59	3.05	4.44	2.92	3.86	2.73	3.78
60–64	2.76	4.19	2.58	3.54	2.47	3.44

ration with increasing age in the Welsh steel-workers than in the Busselton men. Between 21 and 64 years, F.E.V._{1.0} declined by 40 per cent. in the Welshmen compared with 35 per cent. at Busselton. Comparative deteriorations with increasing age were more marked with F.V.C. than with F.E.V._{1.0}, F.V.C. declining between 21 and 64 years by an average of 31 per cent. in the Welsh steel-workers compared with a 21 per cent. decline in the Busselton men.

Payne and Kjelsberg (1964) estimated F.E.V._{1.0} in Tecumseh men and found a decline in values in men between 21 and 64 years of approximately

grades of bronchitis. It is hoped that longitudinal observations on this population will determine whether subjective symptoms or objective information such as audible productive cough, F.E.V._{1.0}, or F.V.C. are the more valid screening for eventual pulmonary disability.

CONCLUSIONS

The greater decline with age in the ventilatory capacity of Welsh steel-workers than of Busselton or Tecumseh men strongly supports previous evidence from subjective symptoms about environmental influences and pulmonary morbidity. Longitudinal studies should confirm these findings, although changing smoking habits or control of air pollution could minimize future differences between populations. Hong and Gandevia's audible productive cough test was shown to have empirical validity under Australian conditions, and it remains to be seen if this test is of better predictive value than subjective evidence of chronic bronchitis (Q.10) in relation to subsequent pulmonary morbidity.

Epidemiological respiratory studies are of increasing value with the wider adoption of standard questionnaires and objective tests of pulmonary function. In future they should provide important guides of progress towards control of inhaled respiratory irritants.

The authors gratefully acknowledge the financial and personal assistance of the Raine Foundation; Bank of New South Wales; Royal Perth Hospital Research Fund;

University of Western Australia; National Heart Foundation of Australia; Boehringer Ingelheim; Geigy Australia; Australian Hoechst; F. Clayton, Busselton; J. T. Carr, W. A. Health Education Council; J. Scaf, Gest-Coco Cola; Dr W. Davidson, Dr V. Blackman, and the staff of the Public Health Laboratories; Mr T. Noonan and Miss G. Mathie of Busselton District Hospital; and the many voluntary helpers in Busselton, especially Mr Derek Snowden of Apex. They also thank Dr Bruce Watson for helpful suggestions and Professor Bryan Gandevia for advice and criticism concerning this paper.

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